Development of a reduced-order model of an industrial billet heating furnace

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Poster Abstract

This work is part of the ongoing efforts under the Audit Furnace project to develop a reduced-order model (ROM) that allows for fast analysis of combustion, fluid flow and heat transfer processes that occur inside industrial furnaces. A billet heating furnace is considered here, which uses propane as fuel and processes circa 5000 kg of material per hour with a billet temperature set point at the exit of 745°C. The billets are cylindrical and move inside the furnace along its longitudinal direction while burners are located along the entire furnace length and combustion gases exit to a collector below the furnace. The furnace is also approximately cylindrical (inner cross section). The developed model is based on solving energy and mass balances for a relatively small number of zones in which the furnace is divided, while describing the heat transfer processes inside each zone through correlations and solutions for simple geometries. The combustion process is modeled considering the complete combustion of the fuel in a single step reaction, which allows determining the energy released in each zone and the composition and temperature of gases according to the stoichiometric relations and excess air. The dependence of the gases properties with temperature is taken into account. Convective heat transfer between combustion gases and billets is modeled using existing correlations in the literature for simple geometries, while the heat transfer by thermal radiation is modeled using the solution of the radiative transfer equation for a volume of participating medium enclosed in an annular region. The ROM outputs are the mean inlet and outlet temperatures of the combustion gases and billets, mass flow rates, heat transfer and

efficiency of each zone as a function of the operating conditions of the furnace. Results were compared with experimental data from energy audits and a fairly good agreement was found. To improve model outputs, results for a single zone were compared with Computational Fluid Dynamics (CFD) simulations (see Costa et al. [1]), and Machine Learning (ML) techniques were employed to increase model accuracy without significantly increasing computational load (see Santos et al. [2]).

Keywords: energy efficiency, modeling, CFD, machine learning.

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